



NUMI targets

Down until ~ Nov. 1 to replace target

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 1

Outline:

- Description of a NUMI target
- Operational history
- Latest target failure (NT-04) - do we understand how ?
 - It started with an internal water leak ... And then a pressure spike
- Do we have a way to prevent Target NT-05 failing in similar fashion ?
 - Cranking helium pressure back up to 23 PSIG should do this.
- Next spare (NT-06) ready in spring 2011.
- (If have time) some details/pictures of previous target failures



NUMI MINOS target

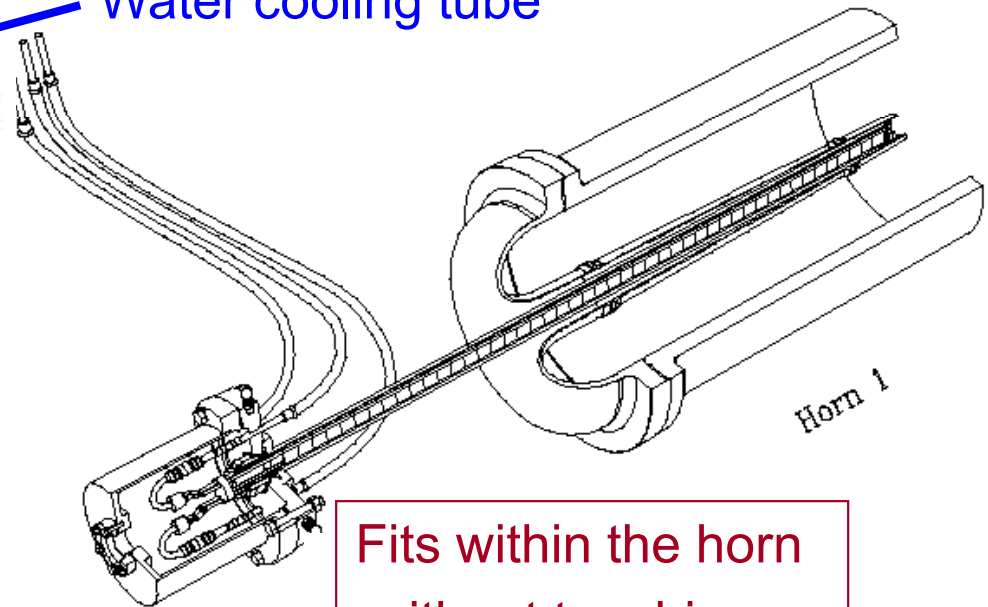
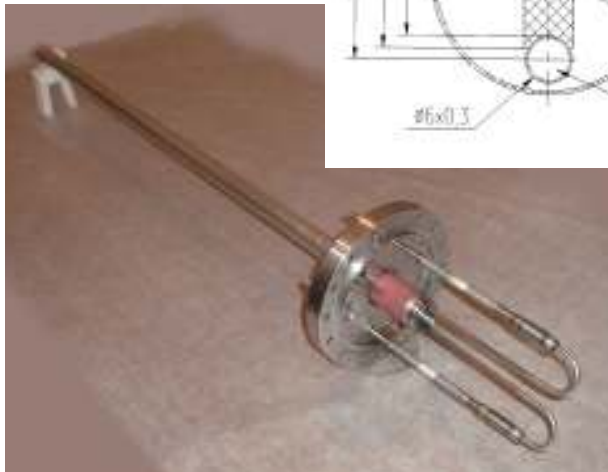
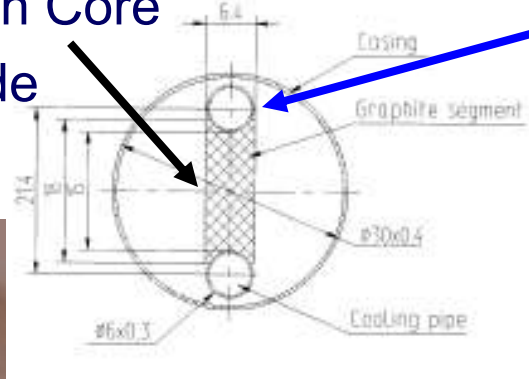
A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 2

2 int. length long; narrow so pions get out sides without re-interacting



Graphite Fin Core
6.4 mm wide

Water cooling tube



Fits within the horn
without touching.

Every pulse, center heats to 330 C in 10 micro-seconds, cools to 58 C in 2 seconds



NUMI variable beam spectrum design

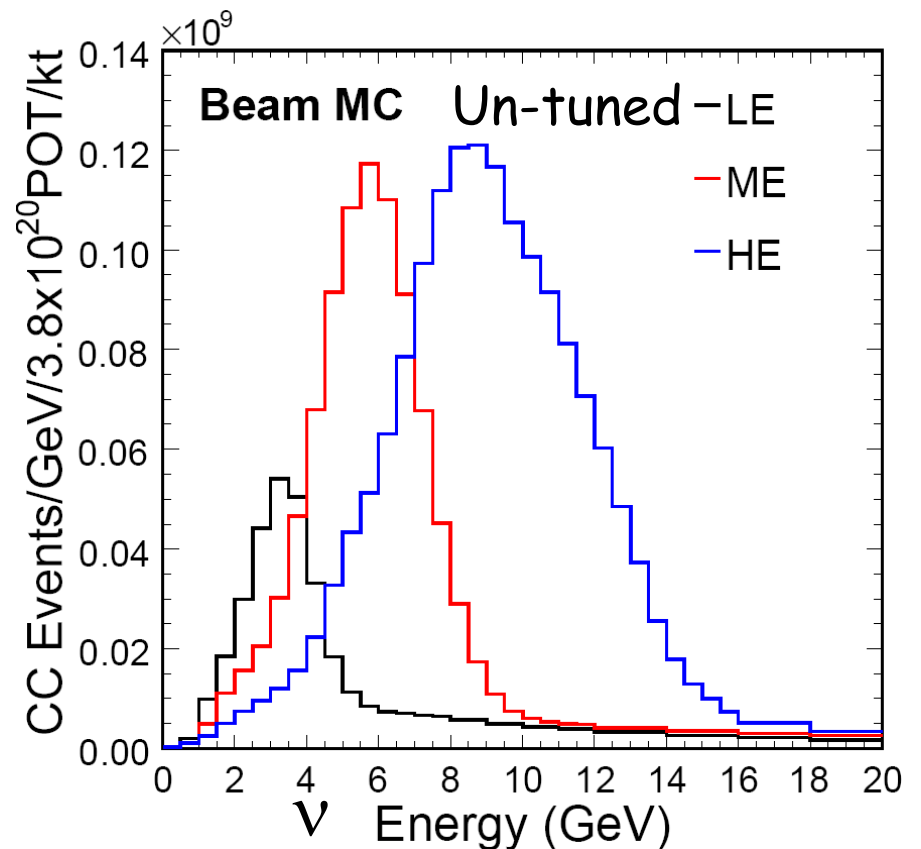
A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 3

NUMI was designed before Δm^2_{atm} was well known.

Target can move over 2.5 m range, changing neutrino spectrum,
allows match to oscillation L/E

Oscillation maximum is actually 2 GeV,
so almost all running has been \sim LE.

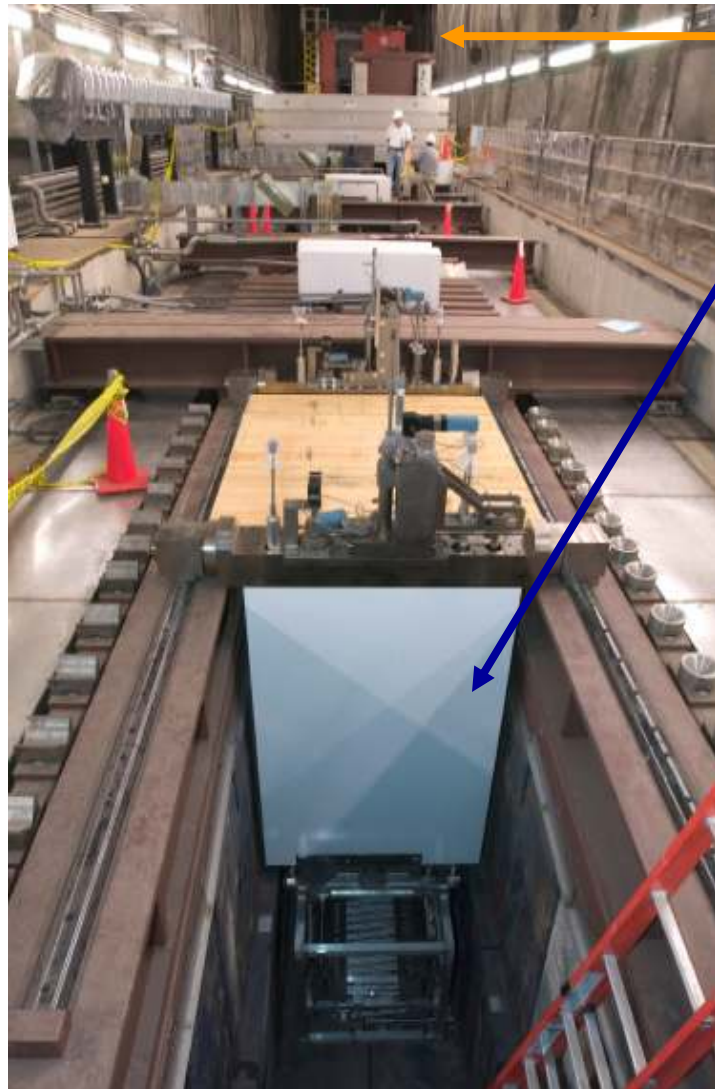
Running with other locations has been
useful for studies of systematics





MINOS Target carrier

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 4



Work cell

Target module in beam-line

1st target being removed





NT-04 residual radiation

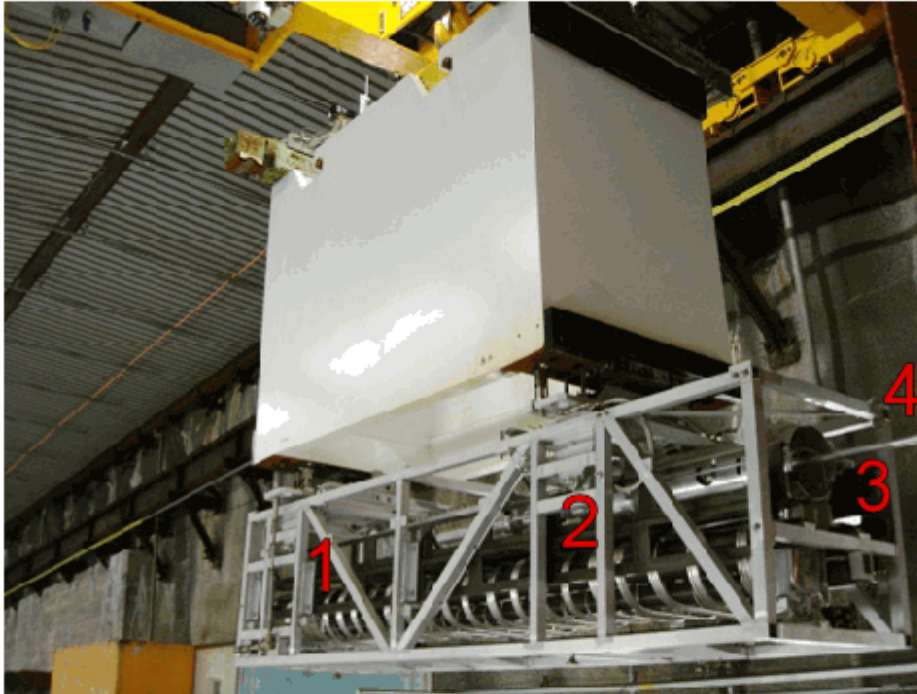
Tip would give weekly dose limit in 4 seconds

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 5



FERMILAB
ACCELERATOR
DIVISION

DATE: 9/21/10 TIME: 0900 PURPOSE: movement survey RWP #



NUMI Target Beam Right

Doserate
@ 1 foot

Point (mR/hour)

1	4000
2	10000
3*	40000
4	15000

All Dose Rates Below <u>N/A</u> mR/hr Unless Noted.		Bkgd <u> </u> cpm		Highest Dose Rate Found <u>15000</u> mR/hr at 1 ft.	
Inst Type: <u>teletector</u>		Wipe # <u> </u>	Reading <u> </u> ccpm	Wipe # <u> </u>	Reading <u> </u> ccpm
Inst No: <u>4</u>		<div style="font-size: 2em; font-weight: bold;">N/A</div>			
Batt/Source Chk: <u>sat</u>					
Cal. Due Date: <u>6/2011</u>					
LEGEND Numbers appearing on map are mR/hr @ 1 ft readings unless denoted with symbols below * = mR/hr @ contact A = Air Sample ○ = Wipe ⊕ = Floor wipe		Beam Off: Date: <u>9/17/10</u> Time: <u>1109</u>		Note: RSO approval required to work in areas where it is: >100 mR/hr @ 1 foot OR >100 CCPM on a wipe. Comments: <u> </u> Surveyed By: <u>Busch</u> Reviewed By: <u> </u>	

REVISED 9/24/10

* note: point #3 was taken on contact with the target tip, with the target in the LE 100 position



Experience with MINOS targets before NT-04 failure

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 6

1st Target took beam for over a year. Two problems:

- water leak soon after turn-on; back-pressured with Helium to keep water out
- target motion drive froze up after year of operation - stuck in High Energy focus

2nd Target ran 3 years, replaced when neutrino spectrum changed ~ 10%

3rd Target ran 1 year, failure at target tube support ceramic

4th Target ran 3 weeks, failure at target water line and helium vessel

	Max. Proton/pulse	Max. Beam Power	Integrated Protons on Target
Target Design specification	4.0e13 p.p.p. <i>at 120 GeV</i>	400 kW	3.7 e20 p.o.t. or 1yr minimum lifetime
1 st target	3.0e13 p.p.p.	270 kW	1.6 e20 p.o.t.
2 nd target	4.0e13 p.p.p.	340 kW	6.0 e20 p.o.t.
3 rd target	4.4e13 p.p.p.	375 kW	3.0 e20 p.o.t.
4 th target			0.2 e20 p.o.t.



down-time due to NuMI target

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 7

Target failures cost:

39 days during commissioning and
22 days of 1428 otherwise "beam available" days
(5/1/2005 -> summer shutdown)

So 2%- 4% downtime (*count commissioning or not*)

This NT-04 failure will add ~ 44 days of down-time.

A target change-out takes about 2 weeks.

*Rest of down-time because don't have spare ready yet.
(construction of a spare ~ 1year)*

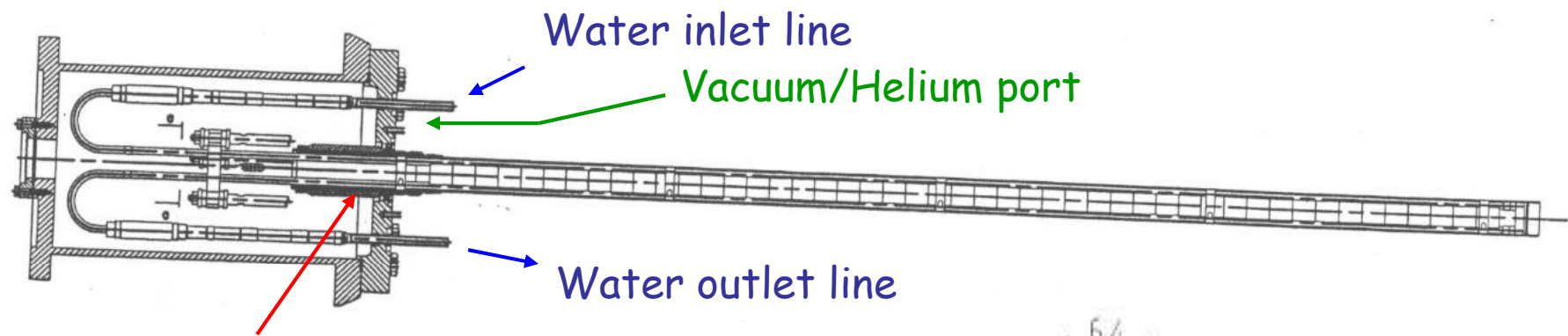
Uptime: NuMI was taking beam 73% of days 5/1/2005 - 8/21/2010

*accumulating $1.07e21$ P.O.T. at 120 GeV
→ 0.65 MW-yr of beam power*

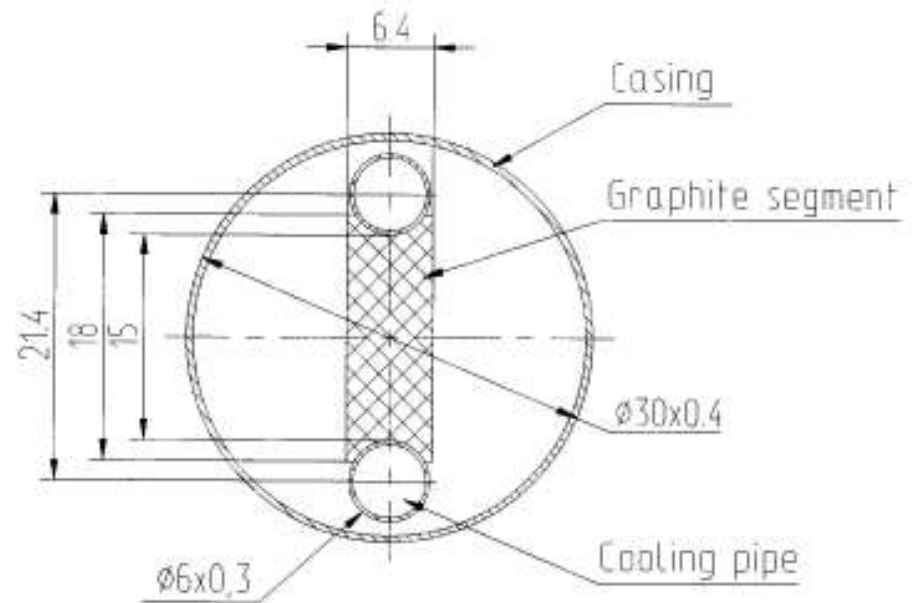


Target

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 8



Ceramic electrical insulator





NT-04 target tip

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 9



See water drip, corrosion looks like left by water.

Other tests: See tiny hole in top during smoke-test.

See evidence of tiny water holes on Be window.



What upstream "window" looks like:



What it should look like



Most of Beryllium is on floor
of target pile , although

Beryllium window shard
resting on upstream baffle:





NT-04 failure

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 11

Target developed a small internal water leak to helium volume.
Amount of water was small enough to not be obvious during beam scans

Sept 9 21:40 pressure spike, knocking out upstream window,
and producing holes in downstream target tube - helium leak.
beam permit stops beam because of helium leak.

How big a pressure spike? ~ 100 psi to break window loose,
(about me stepping on window with my heel).
Note the 30 psi rupture disk at top of target pile did not rupture.

A STORY

Beam radiation dissociated water into hydrogen and oxygen,
which had nowhere to go - helium volume was tight to outside air.

Sept 9 21:40 Something ignited the hydrogen,
blowing off the upstream beryllium window and creating holes near target tip,

AN ALTERNATE STORY:

Target filled with water, water heated by beam spill,
pushed off upstream window.



Some extra timeline

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 12

Sept 8 stopped beam running to move target from LE100 to LE250

Sept 8 19:00 Beam scan of target looked pretty OK. Not filled with water.
(then beam off due to BPM, accelerator problems)

Sept 9 17:00 beam returned, run a few hours

Sept 9 21:40 beam permit stops beam because of helium leak.

Sept 10 4AM beam scan of target looked pretty OK. Not filled with water.

Flow helium, with beam permit set to trip if flow dropped.

Run beam until Sept 17.



Other info related to NT04

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 13

Hole in water line is presently small:

Did pressure test, fill with helium to 31.5 psi and capped off.

Dropped to 30 psi in 5+ hours.

(No notable drop in target RAW skid water level week after failure)

Sept 21 Survey in work-cell saw tip 1.5 mm low, with some water visible.

The 1.5 mm droop is possibly from weight of water ?

Since target is fin shaped, this vertical mis-alignment is not important for physics signal, but

Think water level is below smoke geyser, but above much of downstream Beryllium window.

Graphite fin still well aligned (beam scans and optical survey)

Bottom line:

Water hammer on delicate welds of water lines likely failure point.



NT04 problem - solution for NT05 ?

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 14

NT01 had similar water leak, but not helium leak.
We ran it for a year by over-pressuring the helium (23 PSIG),
so helium went into water system, not water into helium volume.

NT02 was also run at 23 PSIG helium pressure.

NT03 was run at 23 PSIG until Dec 2, 2009, then reduced to 12 PSIG.
It failed at end of April 2010, (possibly in same way).

NT04 was run with 6 PSIG helium pressure.

Pressure reduction was to bring us more rapidly into compliance
with FNAL pressure vessel guidelines, not for technical reasons.

We should run NT05 at 23 PSIG.

*Mechanical Support Dept. to write hazard analysis,
and (on longer time scale) Engineering note. (Dir. Exception?)*



Other actions for NT05

A. E. M.
October 4, 2010
Jim Hylan/FNAL
Page 15

Radiograph NT05 before installation, to check internal welds at tip

NUMI-only spills are currently significantly higher intensity than Mixed-mode spills, but not much time spent in NUMI-only.

NuMI-only has been 10% over design intensity - $4.4e13$ POT/spill max

Will limit intensity of NUMI-only spills to what we get in Mixed-mode, to eliminate the highest stress pulses.

Cost is $\sim 1\%$ of integrated luminosity.

Start autopsies of previous targets next spring.

Finishing a work-cell at CO/RHF to work on horns & targets



Backup slides

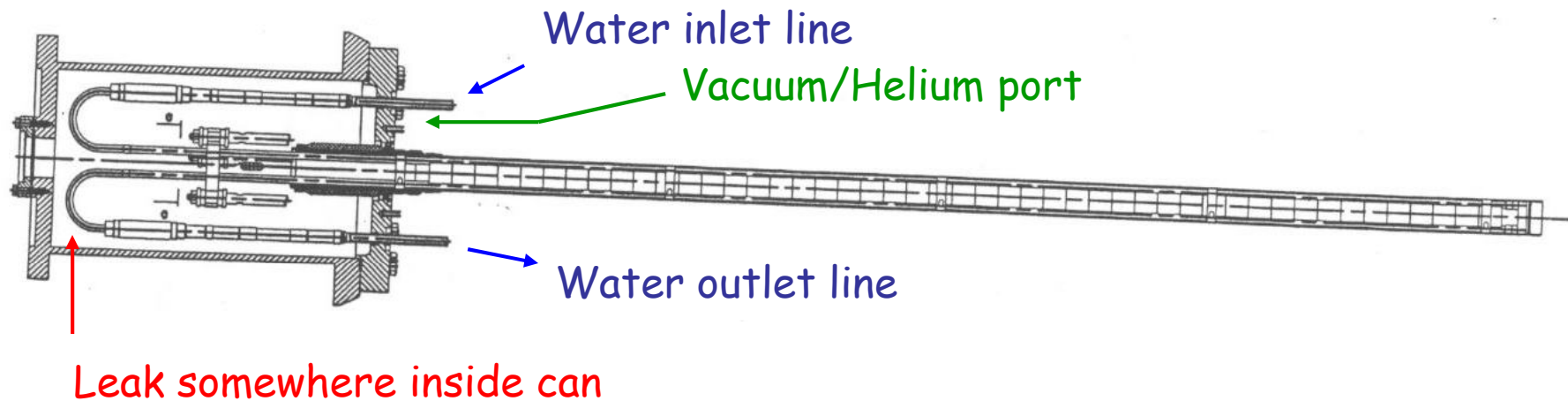
A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 16



Target NT-01 water leak

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 17

On March 23, 2005 water leaked from cooling line into vacuum can, flooding target.



After draining target, we pressurized the can with 23 psig helium
(was planning to use helium for high power running anyway)

Helium bubbled through leak to water line, keeping water out of target.



NT-01 Frozen drive shaft *target replaced because could not move it to LE position*

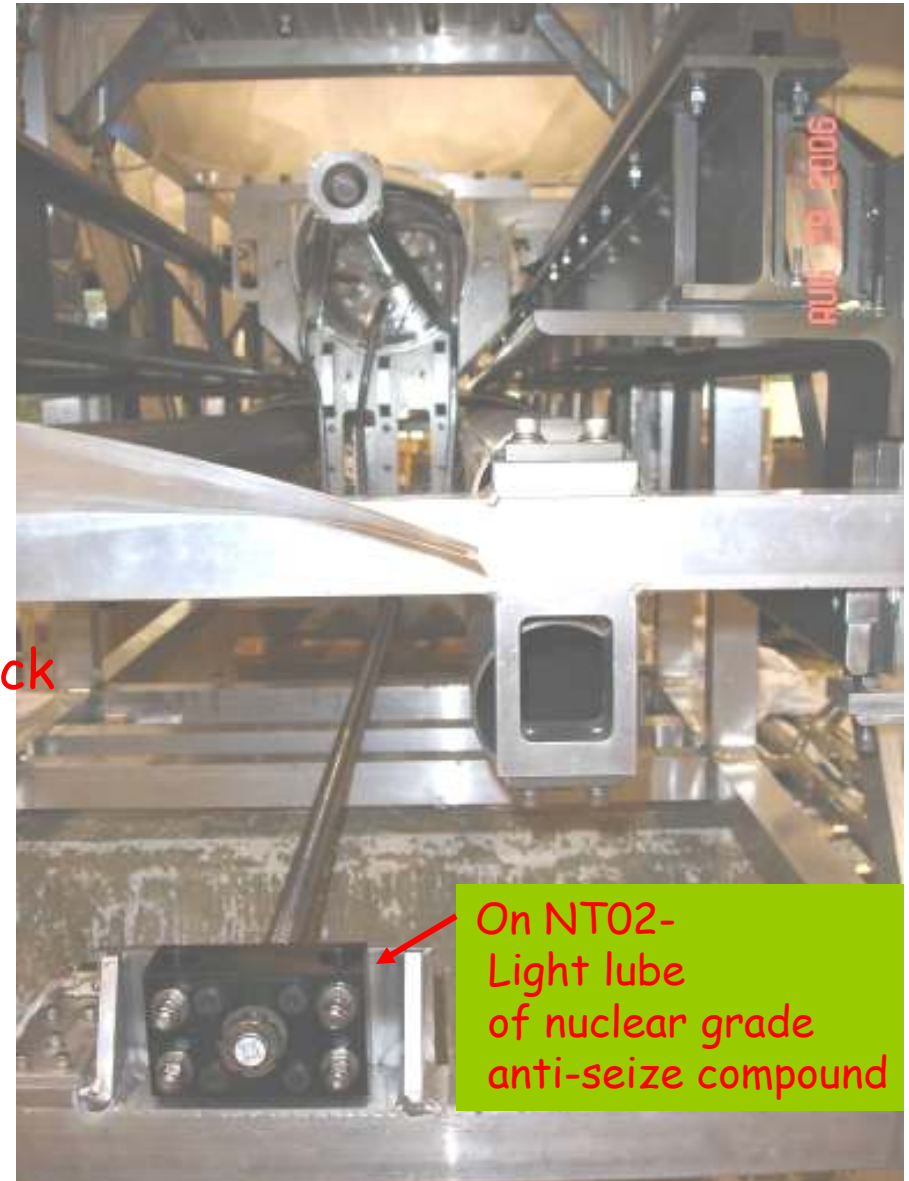
A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 18

After month-long test in High Energy position
drive shaft would not rotate to move target
into Low Energy position

Changed to spare target + carrier (NT02)
(drive also became sticky after beam)

NT03 onward, changed to graphite bushing
NT-03 drive moved smoothly at the end
of it's year lifetime.

Old jammed pillow-block



On NT02-
Light lube
of nuclear grade
anti-seize compound



Target remote drive coupler failure (repaired)

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 19

Air + radiation = nitric acid

Nitric acid atmosphere

→ hydrogen embrittlement of high
strength steel

→ steel cracks



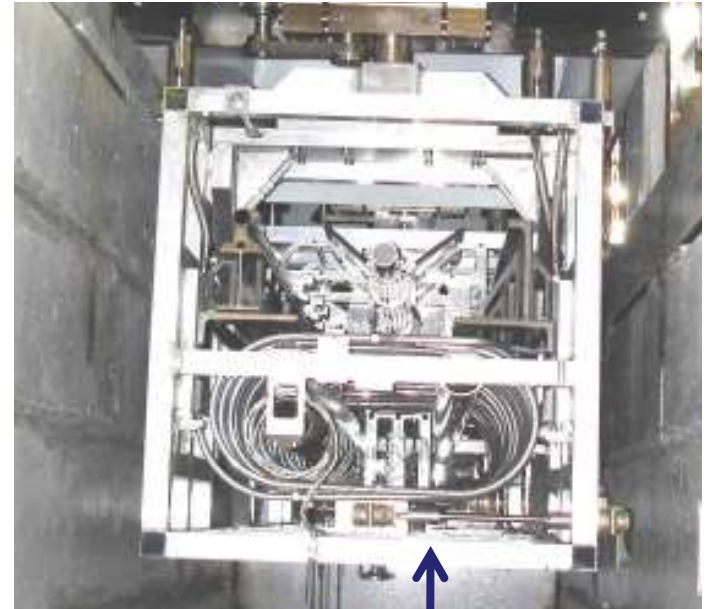
High strength steel bolts in couplers on
target

drive linkage failed, so could not move
target

to different position.

Have changed to non-high-strength bolts.

No more failures of this type.





NuMI 2nd target depletion (ZXF-5Q amorphous graphite)
NT-02 replaced when spectrum shift became too large.

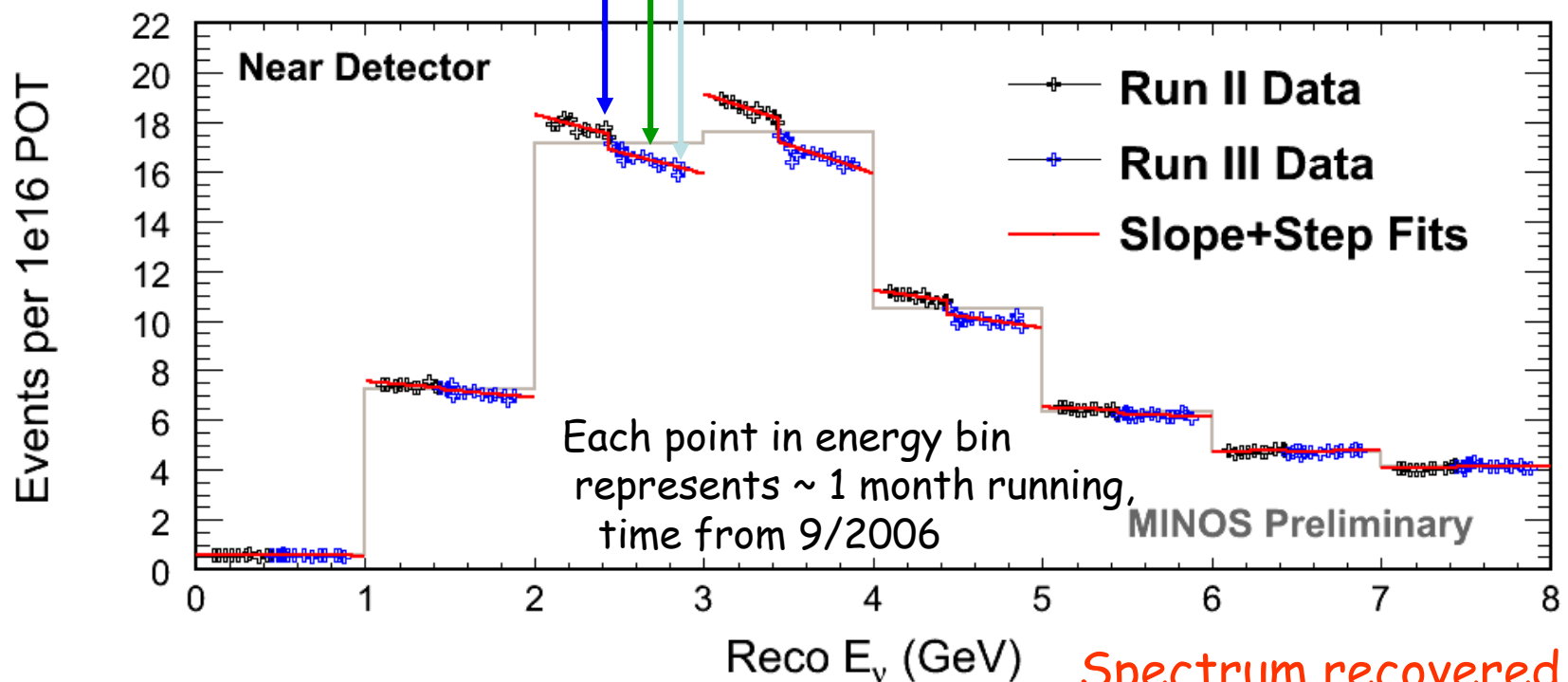
A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 20

Gradual decrease in neutrino rate attributed to target radiation damage

Decrease as expected when decay pipe changed from vacuum to helium fill

No change when horn 1 was replaced

No change when horn 2 was replaced



Spectrum recovered when new target was inserted



NT-03 failure

A. E. M.
October 4, 2010
Jim Hylen/FNAL
Page 21

Helium leak developed, and target fin moved beam-left.

We re-adjusted target so parallel to beam again, and ran another two months.

Exam showed leak at ceramic insulator at base of target - presumed cause is failure of braze joint or ceramic causing (X=4 mm, Y=8 mm) displacement of target tip

Exam also showed helium leak/damage at bottom of target tube

- presumed collateral damage from horn current with target resting on horn conductor (which limited the vertical displacement to 6 mm)

(Since target is fin shaped, vertical mis-alignment is not as important)

